

## Vertical fine structure and time evolution of plasma irregularities in the $E_s$ layer, observed by a high resolution $\text{Ca}^+$ lidar

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The vertical fine structures and the time evolution of plasma irregularities in the sporadic  $E$  ( $E_s$ ) layer were observed via calcium ion ( $\text{Ca}^+$ ) density measurements using a resonance scattering lidar with a high time-height resolution (5 s and 15 m) at Tachikawa (35.7°N, 139.4°E) on December 24, 2014. The observation successfully provided clearer fine structures of plasma irregularities, such as quasi-sinusoidal variation, localized clumps, “cats-eye” structures, and twist structures, in the sporadic  $\text{Ca}^+$  ( $\text{Ca}_s^+$ ) layers at around 100 km altitude. These fine structures suggested that the Kelvin-Helmholtz (K-H) instabilities occurred in the neutral atmosphere whose density changed temporarily or spatially. The maximum  $\text{Ca}^+$  density in the  $\text{Ca}_s^+$  layer was two orders of magnitude smaller than the maximum electron density estimated from the critical frequency ( $f_oE_s$ ) observed by the ionosonde at Kokubunji (35.7°N, 139.5°E) simultaneously. The correlation showed a strong positive correlation with a coefficient of 0.91. These results suggest that  $\text{Ca}^+$  contributes forming the  $E_s$  layer as well as major metallic ions  $\text{Fe}^+$  and  $\text{Mg}^+$  in the lower thermosphere. Moreover, the formation of a new  $\text{Ca}_s^+$  layer at 110 km and the upward motions of the  $\text{Ca}_s^+$  layers at 100 km and 110 km were observed just after the sunrise time at the conjugation point and before the local sunrise. Although the presence or absence of a causal relationship with the sunrise time was not clear, a possible explanation for the formation and the upward motions of the  $\text{Ca}_s^+$  layers was the occurrence of strong eastward winds at around 100 km, rather than the enhancement of the eastward electric field.